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Ministry of the ENVIRONMENT

Underdrained Filter Systems Whitby Experimental Station

(Interim Report–Part 1)

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Environment Ontario

INTERIM REPORT

ON

UNDERDRAINED FILTER SYSTEMS

AT

WHITBY EXPERIMENTAL STATION

PART I

By

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continued . . .

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ABSTRACT

As a program of the Technical Services Section, Private Waste and Water Management Branch, six underdrained filter beds were put in operation at the Ontario Hospital, Whitby, Ontario. These have been tested continuously since September 1969 by dosing them with septic tank effluent obtained from domestic sewage originating in the Hospital Staff quarters.

This report deals with pilot plant study of the treatment of septic tank effluent by filtering through 30 inches of commonly available sand with different effective grain sizes (D_{10}) 0.15 to 2.5 mm. and different uniformity coefficients (C_u) 1.2 to 4.4, for a period of 9 months between September 1969 and July 1970. The filter bed loading rate of sewage was approximately 1 gal/sq. ft./day, as a trickle flow effluent discharged from a conventional septic tank through perforated 4 inch diameter No-Corrode or A.B.S. pipes.

The final effluents from the filter beds had analyses for B.O.D. and Suspended Solids in the range of 3 to 6 mg/1 and 1 to 3 mg/1, respectively, for 50% of the time and both under 10 mg/1 for 85% of the operating time.

The useful life of beds containing filter media of D_{10} = 0.15 mm. and 0.19 mm. was limited to only four months at the above sewage load. The large grain filter media of D_{10} = 2.5 mm. treated the sewage well enough to result in an effluent which is suitable for discharging into a water course.

The stabilization of nitrogen compounds to nitrates as well as the complete oxidation of free ammonia took relatively longer time for commencement of the treatment processes as compared with B.O.D., C.O.D., S.S., etc., which attained low values within 2 - 5 days from the starting up of the operation.

There are very wide fluctuations in the total and fecal Coliforms in the effluents of the weekly samples from all the beds. The bacterial count in the effluents, when considered in 85% of the samples through sands of D_{10} = 1.0 mm. and 2.5 mm. was relatively higher than that in the effluents through finer media with D_{10} less than 1.0 mm.

The water usage in the houses was in the range of 20 to 42 gal/capita/day. The average usage in the community was 31.4 gal/capita/day.

INTRODUCTION

The sand filter is considered to be an efficient device for the treatment of household sewage in areas where the conventional sub-surface disposal methods are impractical. One specification[1] for filter media calls for a clean sand having an effective size between 0.3 and 0.6 mm. and a uniformity coefficient of not greater than 3.5.

The Housing and Home Finance Agency[2] recommends an effective size of 0.25 and 0.50 mm. and uniformity coefficient of not greater than 4.0.

The Ohio Department of Health[3] specifies sand with effective size between 0.35 and 0.50 mm. and uniformity coefficient not greater than 3.0.

According to Fair and Geyer[4], sands having uniformity coefficients between 1 and 5 will have practically the same hydraulic characteristics provided the effective size of the sands is the same.

Material with rigid specifications as mentioned above is difficult to obtain in Ontario.

It was decided to use the widely available sands classified at the gravel pits as asphalt sand, block sand and concrete sand. Effective sizes between 0.15 and 2.5 mm. and the uniformity coefficient between 1.2 and 4.4 were considered to be acceptable for this program.

LOCATION

The experimental facilities were constructed on Provincially owned land at Whitby Ontario Hospital. The domestic sewage from dwelling units occupied by the hospital staff is used for the studies.

There are eight houses and a comfort station which are not connected into the hospital sewage system but instead, divert flow to a septic tank system as shown on Figure 1.

The residents of these houses are full time hospital employees. Some of the residents are shift and some are daytime workers. The quality of the sewage is that pertaining to a small community of residents of various ages and of various socio-economic backgrounds.

The site of the chosen facilities is located in the farm area of the hospital, situated north-west of the intersection of Victoria Street and Farm Road and close to the septic tank system.

BUILDING

A timber building with plan dimensions of 36' x 12' and with a central tower was erected. The building is equipped with electrical and water services. The pipe lines necessary to carry the sewage from the septic tank to the building and effluent from the building to the septic tank, as well as the electric cable for operating the pump in the septic tank, have been installed.

Six filter boxes, three on the north and three on the south, are located outside and adjacent to the building.

Figures No. 2, 3, 4 & 5 show the details. (Appendix)

PROCESS OUTLINE (Sketch A)

The sewage is pumped from the dosing chamber of the septic tank into overhead holding tanks. From there it flows by gravity downwards through regulating valves and measuring devices into the six dosing tanks. These tanks are provided with electrically operated valves which permit discharge of sewage at the required frequency onto the corresponding filter beds. The beds contain filter media of different types and sizes. The treated effluent after quantity measurement, is

discharged into the tile field through the distribution box. The entire system is so arranged that the quantity of sewage can be varied to load the filters. Moreover, samples of the sewage and the treated effluent from each filter can be collected. The samples are sent to the Public Health laboratory for bacteriological analysis and to the Ministry laboratory for chemical analysis.

PLANT

Septic Tank and Pump

The septic tank (Drawing 2) is made of poured-in-place concrete. It consists of two retention chambers and a siphon chamber. The first compartment has a length, width and depth of 8' 6", 6'6" and 4' 0" respectively corresponding to the volume of 1,380 Imperial gallon; the second compartment has a length, width and liquid depth of 4' 0", 6' 6" and 3' 7" respectively corresponding to a volume of 580 Imperial gallons. The siphon chamber had dimensions of 11' 6" x 6' 6" wide and was originally provided with a 4" siphon discharging into a distribution chamber. The siphon has been removed and the height of the outflow pipe has been raised to $14\frac{1}{2}$" for increasing the storage capacity of this chamber. The sewage pump has been installed in this chamber. The flow rate and the quantity of sewage collected over continuous 30 hours had been measured. The volume collected was 14,000 gallons/day.

Pump

The sewage pump is 2 horsepower, 220 v., 1740 r.p.m. It operates on float control to start when the level of sewage reaches a certain height and cuts out when it reaches the low level in the sump or when the overhead tank in the building is full. The automatic cut off arrangement protects the pump from running dry, also preventing overflow from the overhead tanks.

PLANT (Cont'd)

Overhead Tanks

There are two, 250 Imperial gallon overhead tanks connected to their outlets through valves into a common discharge pipe. Sewage from the pumping chamber of the septic tank passes through the flow meter located at the ground floor, enters at the top of the overhead tank. The float control for the high and low level in this tank controls the operation of the sewage pump. The outlet from the tanks is provided with an electrically operated valve in addition to the manually operated valves. An overflow pipe, with a connection for draining and cleaning the tanks when necessary, permits return of sewage to the pump chamber of the septic tank. fig. 4.

Proportioning Devices

Proportioning device consists of a galvanized iron tank 18" x 18" x 10" deep with tipping bucket arrangement for dividing the flow into two equal halves. A lever arrangement connected to the tipping mechanism actuates a recorder and shows the number of tippings. A screw with a balancing weight is provided for adjustments to obtain equal volumes in the two pans of the tipping bucket. There are nine tipping buckets located on the second floor each provided with valves and connecting pipe work to permit varying the distribution of the quantity of the sewage for changing the loading rates for the filters. fig. 4.

Dosing Tanks

There are six, 250 Imperial gallon dosing tanks each provided with motorized valves in addition to the manually operated valves. The sewage from the tipping buckets may be stored in these tanks for dosing at the desired frequency,

programmed with the motorized valves or allowed to pass through directly as a dribble flow to the filter beds. The motorized valves could be controlled by an electrically operated timing device.figs. 3 & 4.

Filter Boxes

There are six rectangular filter boxes. They are 12' 0" x 10' 0" x 4' 0" deep made up of 3/4" plywood. Inside each box, plastic sheet has been used as a lining material.fig. 3.

On the bottom of each box are two lengths of 8' 0" perforated collector pipe, joined by a header. The outlet from the box enters the building at the floor level and the effluent discharges into a tipping bucket. The quantity of sewage flowing out of the bed is measured. Above and around these collector pipes to a height of 6" from the bottom is 1" to 1½" crushed stone. This is followed by 30 inches of the filter media. Above this is 2 inches of crushed stone, on which rest the three perforated distribution pipes 8' 0" long with a header and connected to the dosing tank. These distributors are surrounded by crushed stone. The box is then covered with top soil.

The filter sands in the boxes had the following characteristics:

	Bed No.	D_{10} mm	C_u	"K" cm /sec.
Asphalt Sand	4	0.15	2.8	2.19×10^{-2}
Concrete Sand	1	0.19	4.4	3.61×10^{-2}
Block Sand	2	0.30	4.1	9.0×10^{-2}
Foundry Slag (Standard)	3	0.60	2.7	3.36×10^{-1}
Fine gravel with sand	5	1.0	2.1	9.6×10^{-1}
¼" gravel	6	2.5	1.2	4.84×10^{0}

Collector Tipping Buckets

For measuring the quantity of effluent from the collectors, each filter box has a tipping bucket similar to those mentioned before. These are located at the ground floor. The measured effluent discharges into the 4" drain pipe connected to the distribution chamber of the septic tank, and then flows into the tile field.

OPERATION

The plant, with necessary calibration, adjustment and repair of leaks, has been in operation since September, 1969.

As the first part of the study, keeping other variables constant, sewage at the loading rate of approximately one gallon per square foot per day is being discharged into the filter beds. The only variable is the filter media.

There is no definite frequency of loading, but the septic tank effluent is pumped as collected and, therefore, an actual representation of conditions of operation of a household system is achieved. Samples of the raw sewage, septic tank effluent and filtered effluents are delivered to the laboratory for analysis.

Records are maintained for the amounts of fresh water used in the residences and the sewage pumped from the septic tank to the overhead tank. Daily readings were observed from the counters attached to the tipping buckets to determine the quantities of sewage going in as well as that discharging out of each filter bed.

The chemical and bacteriological analyses of 24 hour composite samples of septic tank and filter bed effluents were carried out by the laboratory for the various indicators to determine the degree of treatment of the waste. A typical

analysis is shown in Table 1. These indicators are B. O. D., C. O. D., nitrogen as free ammonia, organic nitrite and nitrate; phosphates total, ortho and poly; solids suspended and total; surfactants as ABS and coliform total and fecal. In addition, observations for temperature, pH values and dissolved oxygen content are recorded. Analyses of raw sewage before discharging into the septic tank are given in Table 2. These are of composite samples collected from the manhole nearest the septic tank, on three consecutive days for a period of $1\frac{1}{2}$ hours each. In addition, some samples for determining the presence and reduction of viruses in the effluents were sent to the virology laboratory.

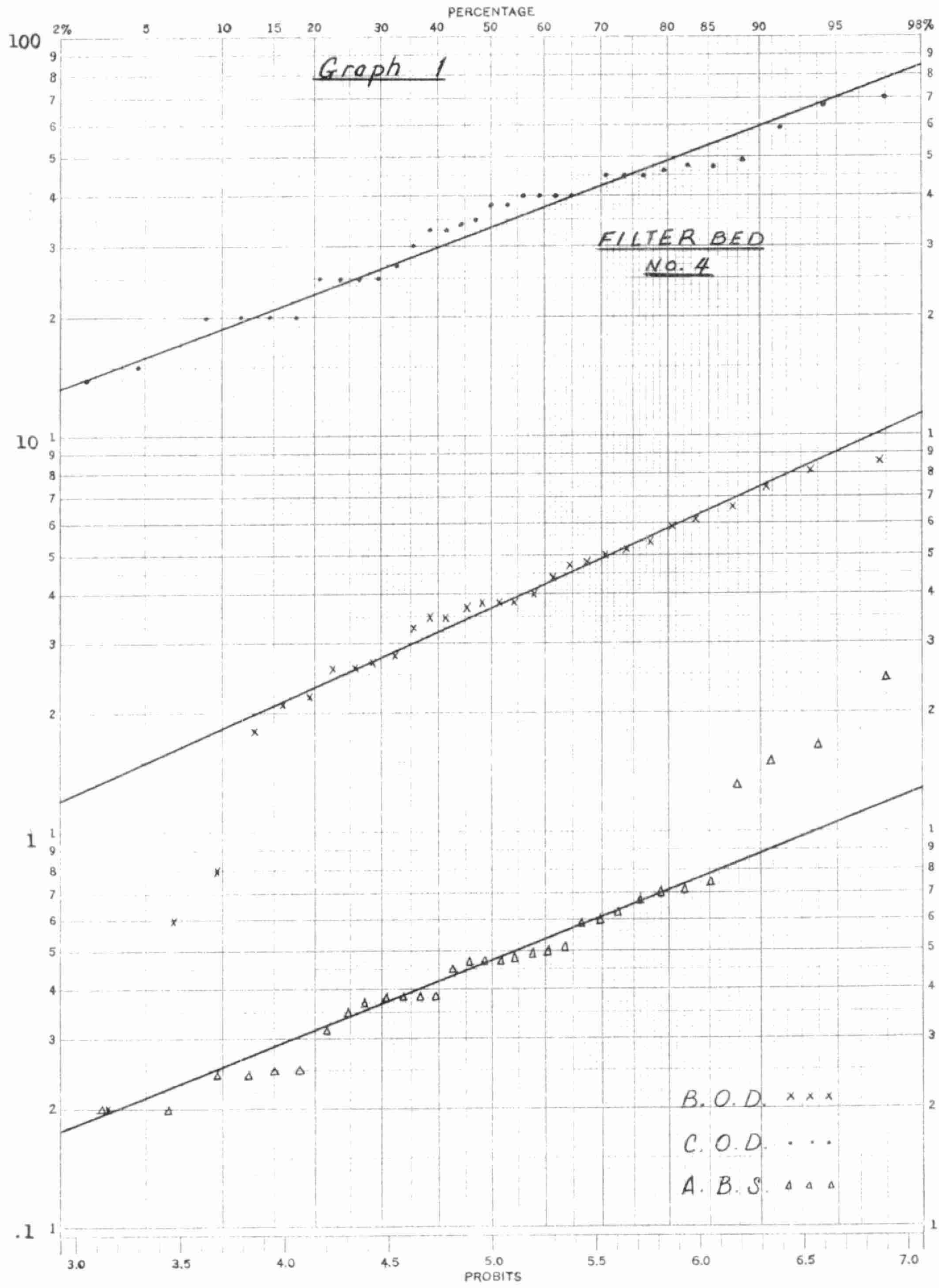
Observations for the average amount of water used per capita-day in the residences from October 1969 to July 1970 is given in Table 3.

An increase in the amount of sewage collected in the septic tank as compared to the amount of water used was observed. It was concluded that the increase was due to seasonal rise in the water table causing excessive infiltration, aggravated by cracks in the sewer line. The eaves troughs, which had originally been discharging rain into the sewer lines, were disconnected.

Filter beds 2, 3, 5 and 6 have been operating continuously without any serious problems. Filter beds 1 and 4, however, with filter media of D_{10}, 0.19 and 0.15 mm respectively, after four months trouble free operation, showed signs of flooding and overflowing early in February, 1970. After intermittent operation and running at reduced rate, they were shut down in July, 1970.

TREATMENT OF DATA

From the laboratory reports it is observed that most of the values had considerable variation from day to day. These values, when plotted on linear



PERCENTAGE
Graph 1
FILTER BED No. 4
B.O.D. x x x
C.O.D. · · ·
A.B.S. Δ Δ Δ
PROBITS

or logarithmic graphs, indicate the variations and limits of the values. Proper evaluation of the data cannot be made by mathematical averages of series of results. Consequently, the graphical method of C. J. Velz[6] was used to treat the data as follows:

(a) The data was arranged in order of ascending magnitude.

(b) A serial number "m" was assigned to each of the "n" values 1, 2, 3, ...n.

(c) The plotting position of each serial number, giving the probability equal to or less than each value, was determined by the ration $\frac{m}{n+1}$ expressed as a percentage by multiplying by 100.

(d) The points were then plotted on logarithmic probability paper. Generally, a straight line developed in the plotting which confirmed that the data were logarithmically normal.

The mean values 50% and the 15% and 85% of the time values for each parameter were taken from the graph (graph 1 is representative) and tabulated for individual beds in tables 4 to 9 and in Summary tables 11 to 16. Similarly, table 10 was made for septic tank effluent.

<u>FILTER BED NO. 1</u> – D_{10} = 0.19 mm, C_u = 4.4

Filter Bed No. 1 was put into regular operation on October 6, 1969. Samples of the effluent were collected on October 7, 8 and 10. These showed a good reduction of Suspended Solids; the values being in the range of 1.2 to 1.6 mg/1. The B. O. D. values for the initial two days, however, were 22.5 and 43.5 mg/1.

The nitrate was less than 0.1 mg/l N, and the free ammonia was 6.60 mg/l N or less. This was followed by a significant increase in the nitrate and ammonia content and a decrease in the B. O. D. The system appeared to be settling down by October 22.

The system continued operation with fluctuations in the values of the various parameters. Without any drastic change in the performace of the bed, the dissolved oxygen content in the effluent, which had been in the range of 2 to 3 ppm, dropped to 0.72 ppm approximately on January 23 and continued generally thereafter between 0.6 and 1.5 ppm oxygen, more often near the lower limit. There was a decrease in the nitrate content, which indicated that the system was becoming anaerobic. Thus, the possibility of clogging the bed was imminent. The values of B. O. D. deteriorated to 33 mg/l. On February 20, the bed showed signs of flooding and the sewage started overflowing. The sewage feed consequently was shut down on February 25, 1970.

After two days' rest period the feed was put on as usual at the rate of 1 gal/sq. ft./ day. The bed started overflowing and, therefore, was shut down again on March 2, 1970 for one week.

On March 9, 1970, the system was again put into operation at a reduced rate of $\frac{1}{2}$ gal./sq. ft/day. There appeared to be a recovery as the nitrate content increased from less than 1 mg /l for 3 consecutive weeks to a range of 2.3-11 mg /l and the maximum value for B. O. D. and Suspended Solids of 6.8 and 8.4 mg/l respectively.

The feed was increased to 1 gal./sq. ft./day on May 5, 1970. This resulted in the increase of Suspended Solids in the subsequent sample of 1.2 mg /l further

increasing to 31 mg/1. The B. O. D. which remained low at about 7.5 mg/1 for three consecutive weeks increased to 30 mg/1.

There were no visible signs of flooding or overflowing, but it had become apparent that after clogging of the filter media, some type of channeling of the flow was in progress.

After soils studies were completed, the conclusion drawn was the possibility of blocking of the collection pipes with fine filter media.

The bed was dug out on July 22, 1970 and the following conditions were observed.

Directly under the top soil cover above the gravel was anaerobic sewage mixed with black sludge and live organisms. The gravel also had black coating. The sludge was more concentrated around the distributor pipes. The distributor pipes inside had a slimy sludge and were removed for cleaning. The upper 6" of the filter media had turned black, whereas the under layer was greyish.

During the process of the removal of the upper layers of gravel, the sewage which had accumulated in the gravel above the sand started discharging through the media to the collector bucket at a high rate. It appeared that the upper layer of the sand had clogged and hence the sewage had not been flowing through the whole area of the bed. During the process of raking of the gravel, a break through the clogging interface occurred, resulting in the rapid discharge of the waste through the bed.

All the filter sand was removed and the gravel at the bottom around half of the bed on the eastern side was taken out. The collector pipe in that area was removed and examined. Contrary to the conclusions of the soil report, there were no traces of sand or any other deposit in the pipe. Consequently, the gravel and the collector pipe in the other half of the bed were left undisturbed.

The filter media had treated the waste satisfactorily to produce an effluent with a B. O. D., C. O. D. and suspended solids in 85% of time equal to or less than 7, 54 and 5.0 mg./1 respectively.

Note: This box was refilled with new sand of D_{10} = 0.24 mm and C_u = 2.8 with an eight inch layer of sand containing 4% Alcan Red Mud.

The ABS concentration had been 2.0 mg/1. There was a slight reduction in phosphates.

In spite of conversion of nitrogenous compound to nitrate, the values of free ammonia remained as high as 17 mg/1. This indicated that the nitrification process did not approach completion.

The useful life of the system if loaded at 1 gal/sq. ft./ day was limited to approximately four months.

A summary of the results is given in Table 4.

FILTER BED NO. 2 - D_{10} = 0.3 mm. C_u = 4.1

Filter Bed No. 2 was put into operation on October 6, 1969 with a feed rate of 1 gal/sq. ft./day. After 48 hours' operation, the values for B. O. D. and suspended solids were 6.2 and less than 1.0 mg/1 respectively. It was after about a week that the oxidation of nitrogenous compounds started showing up in the analyses when the nitrate content increased from less than 0.1 to 2.0 mg/1. After two days it was 8.0 mg/1 and increased to 24.6/1 in the following sample after five days.

The system ever since has been operating satisfactorily, and the summary of the results is given in table 5.

FILTER BED NO. 3 - D_{10} = 0.6 mm. C_u = 2.7

Filter Bed No. 3 was brought into regular operation on October 7, 1969 at the feed rate of 1 gal./sq. ft./day. The B. O. D. after 24, 48 and 96 hours

of operation was 82, 40 and 12.4 mg/1 respectively. The corresponding suspended solids were 31, 11 and 11.2 mg/1. After eight days' operation the B. O. D. and Suspended Solids were 4.8 and 1.2 mg./1 respectively.

The nitrification process was slow and the nitrate content was less than 0.1 mg/1 till after 2 weeks of operation. The free ammonia during this period was high in the range of 33 - 36 mg/1 N. From the 24th of October the nitrate started increasing and by the 19th of November, after 1½ months of start of operation, the nitrate concentrates increased to 38.6 mg./1 (N) and the ammonia concentration dropped to 6.0 mg/1 (N). The system appeared to have become stable and continued performing satisfactorily without any major problem. The values of various parameters are given in table 6.

<u>FILTER BED NO. 4</u> - D_{10} = 0.15 mm. C_u = 2.8

The system was started on the 6th of October, 1969. However, since there appeared to be some leaks in the outlet from the filter box, it had to be shut down for repairs and restarted on the 12th of October. The initial few samples had low B. O. D. 7.0 - 8.0 mg./1 but high suspended solids. By the end of the month, however, the values for B. O. D. and suspended solids had come down to 6.4 and 3.8 mg/1 respectively. The nitrate content was less than 0.1 mg/1 N up to October 27, 1970 and then started increasing with a value of 13.6 mg/1 N on November 12, 1969. There was a slight reduction in phosphates but a good treatment for A. B. S. The values of free ammonia continued to remain high.

The effluent from the bed had been showing dissolved oxygen in the range of 2.8 to 5.0 ppm up to the 21st of January 1970. Most of the values were near the lower limit. These, however, started decreasing further and were often

near 1.5 ppm. This was an indication that the system was becoming anaerobic with the possibility of clogging of the bed.

The bed started overflowing on February 6, and was shut down on February 25, 1970. The analysis of the overflow confirmed that it was raw sewage. After allowing a resting period of 48 hours, it was restarted on February 27, 1970. The bed started and continued leaking slightly, but the effluent produced indicated some treatment of the waste. A filter media sample was collected, analysed and the same conclusions drawn as for filter bed 1. On April 12, 1970, the feed rate was reduced to $\frac{1}{2}$ gal./sq/ ft./day. The bed could take this rate without overflowing. The system was, however, shut down on May 4, 1970.

The bed was dug out on July 27. Since it had been shut down for a long period, the sand was dry and no abnormality could be observed.

The analyses of the effluent are given on table 7.

<u>FILTER BED NO. 5</u> - D_{10} = 1.0 mm , C_u = 2.1

Bed No. 5 was put into commission on October 6, 1970. The B. O. D. value on October 7 was 85.0 mg/1 and continued decreasing in successive samples. The values on the 8th, 10th and 15th of October were 28, 13, and 8 mg /1 respectively. During this period the nitrate content was less than 1 mg /1. On the 22nd of October, after two weeks operation, the B. O. D. had come down to 5 and nitrate started increasing. The Suspended Solids were reduced to 2.5 after fluctuating between 8 and 65 mg /1 previous to this. Although the nitrate concentration increased, the corresponding free ammonia remained high, usually above 4 mg /1. From February 1970, however, free ammonia started decreasing to values often less than 1 mg/1 and sometimes not detected at all.

The values of B. O. D. and Suspended Solids for 85% of the time were equal to or less than 6.2 and 4.2 mg/1 respectively. The values of the various tests are given in table 8.

FILTER BED NO. 6 - D_{10} = 2.5 mm. C_u = 1.2

Bed No. 6 was put into operation on October 6, but had to be shut down on the following day for repair of a leak at the collector pipe. It was re-started on the 15th of October, 1970. After 48 hours operation, the B. O. D. value was 6.6 mg/1 and the Suspended Solids 9.2 mg/1.

There was little formation of nitrate up to the middle of November, the values being less than 1 mg/1. The free ammonia during this period had been, generally, between 24 and 36 mg/1. There had been no problem in the operation of this bed. The values of free ammonia gradually had decreased and showed wide fluctuations. The values ranged between 0 and 18 mg/1 for March to July 1970. Table No. 9 gives the values for various indicators. The B. O. D. and suspended solids for 85% of the time were equal to or less than 10 and 10.5 mg/1 respectively.

DISCUSSION

From the laboratory analyses of the samples it was observed that the conversion of nitrogen compounds into nitrates in the filter beds started at a much later date and took a relatively longer time for the stabilization of the process as compared to B. O. D. or S. S. The difference was more apparent in beds 5 and 6, the last named requiring more than 4 weeks. The reduction in B. O. D. or C. O. D. and S. S. values was affected within 2 to 5 days. The

nitrate content increased but the free ammonia concentration also remained high. It was not until after six months of operation that it dropped to 1 mg /1, often less. Sample results indicated the presence of nitrite, showing that the nitrification processes had not been completed.

Filter beds 1 and 4 provided satisfactory treatment for only 4 months, at which time, overflowing due to clogging of the media occurred. The other beds had been operating without any major problems.

The tracer dye tests in Table 17 show the time taken in each bed for the dye to appear in the collector buckets.

The water used per capita per day for each family (Table 3) was found to vary over a wide range. The average over a 10 month period ranged between 19.8 and 41.9 gallons/capita/day. On the basis of the community, as a whole, the water usage was 31.4 gal./capita/day. During the summer months of June and July the water usage was 40.9 and 33.6 gal./capita/day respectively. In July the consumption rate was lower than that of June, since several members of the community were away on vacation during this month, and less water was used in the gardens.

It has not been possible to draw a water balance for the system from the quantities of water used and the sewage produced. During the period when the water table was high, the ground water had been infiltrating into the waste disposal system. Consequently, the volume of sewage received from the septic tank was much greater than the volume of water used in the residences. During summer months water usage was greater than the sewage collected. This could be attributed to the use of water on the lawns and partly perhaps for the sewage seeping out leaky sewer pipes.

The Summary Tables 11 to 16 show comparative values of the quality of septic tank effluent and filter beds effluents after treatment.

B. O. D.

The values for B. O. D. for all filter bed effluents were low, not exceeding 10.0 mg/1. There appeared to be no direct relationship between the characteristics of filter media with regard to the grain size distribution and the degree of reduction of B. O. D. The lowest values for 85% of the time were equal to or less than 6.2 mg/1 for bed 5. The corresponding values for beds 1 to 4 were between 6.5 and 8.6 mg/1. The highest value of 10 mg/1 was for bed 6.

C. O. D.

The C. O. D. values indicated, as expected, almost the same trend as that of the B. O. D., with the lowest value of 48 mg/1 for bed 5 and highest of 78 mg/1 for bed 6. The values for beds 1 to 4 are between 53 and 56 mg/1.

SUSPENDED SOLIDS

Since for almost 50% of the time the S.S. for beds 1 to 5 had been expressed only as less than 1 mg/1, and the exact points could not be plotted, the graph is not a straight line passing through the points. The values, however, for 85% of the time for beds 1 to 5 were equal to or less than 4.3 mg/1. Bed 6 had the highest values of 10.5 mg/1.

Most of these solids were organic volatiles.

NITROGEN (Free ammonia, nitrite and nitrate)

The progress of nitrification varied in the beds from one to six weeks. There was no general correlation of this process with the grain size of the

filter media in the five beds. Bed No. 6 which had the largest size sand D_{10} = 2.5 mm. took almost five weeks before the nitrate content started increasing from less than 1.0 mg./1. The free ammonia content had remained high in beds 1, 2, 4 and 6 during the first five months, i.e. October 1969 to March 1970 of operation.

Bed No. 2 showed significant reduction of ammonia from the middle of March, whereas beds 1 and 4 had little change till they failed. Bed No. 6 continued showing high ammonia content. Beds No. 3 and 5 had relatively lower values after this period.

The nitrite content in the beds was in the range of 0.6 to 1.0 mg/1. The high content of ammonia and nitrite indicates that the nitrification process was incomplete until March and required longer time for stabilization. From April onward, the time for stabilization of the free ammonia content had become, on the average, less than 1 mg/1 and appeared to be improving with time.

ABS

The analyses for surfactants (ABS) were started at the end of the first week of November 1969, after the beds had been in operation for one month. The septic tank effluent showed 5.0 mg/1 or more, and the effluent from the filter beds averaged 0.78 to 2.0 mg/1 of ABS. The reduction, in general, was 60 to 85%. The lowest amount of treatment took place in Bed No. 1.

PHOSPHATES

The septic tank effluent had a total phosphate (PO_4) content of 68 mg/1, whereas the filter bed effluents showed concentrations between 47 and

58 mg/1. There appeared to be a reduction in the range of 20 - 30% in the beds, but the degree of treatment provided by soils of different effective size grains and uniformity coefficients was not detected.

OBSERVATIONS AND CONCLUSIONS

In a previous publication[1] of 1955, the statistical interpretation on the basis of 56 grab samples of effluents collected from subsurface sand filters at 19 establishments had been made. It had been stated that 50% of the septic tank effluent, that is, those in the middle quartile had a B. O. D. of 70 to 215 mg/1 and S.S. of 60 to 200 ppm. The filter effluent results had a B. O. D. of 2.5 to 11 mg/1, a S.S. of 6 to 22 mg/1 and nitrate content of also 6 to 22 mg/1. It has also been stated that 90% of the time, the B. O. D. and S.S. in the effluent was less than 21 mg/1 and 37 mg/1 respectively.

In a recent study[5] in 1968 by OWRC, reporting on 12 plants and 156 samples, the effluent quality for 50% of the time in terms of B. O. D. and S.S. has been equal to or less than 38 mg/1 and 34 mg/1 respectively. The corresponding values for 85% of the time have been 82 mg/1 and 68 mg/1.

The results of the Whitby study do not show direct relationships between the effective size and uniformity coefficient and reduction in B. O. D. or suspended solids. All filter media with effective size of 0.15 to 1.0 mm and uniformity coefficient of 2.8 to 4.4 produced effluent of B. O. D. and S.S. for 85% of the time equal to or less than 8.6 mg/1 and 4.2 mg/1 respectively. The life of finer media, i.e. D_{10} of 0.15 and 0.19, however, was limited to only 4 months while operating at a loading rate of 1 gal/ft^2/day. The sand with D_{10} = 2.5 mm and C_u = 1.2 had values for B. O. D. and S.S. relatively higher but equal to or less than 10.5 mg/1 in 85% of the samples.

The nitrification process was slow at first, but with time, it is showing trends of stabilization with considerable reduction in free ammonia after about six months of operation.

The effluents from all the systems contained fecal coliforms. Relatively more in the effluent from filter bed, (D_{10} = 2.5 mm sand) was found. There was, however, a considerable reduction in all the systems.

In 18 samples of the effluents, no virus had been detected.

Table 1*

Laboratory Analyses of Effluent

Samples Collected on Nov. 12 , 1969.*

Effluent	NITROGEN PPM				PHOSPHATE (PO_4) MGS/LITRE		COD MGS/1	ABS MGS/1	TSS MGS/1	Volatile Solids MGS/1	Total Solids MGS/1	PH in Lab	BOD MGS/1	Coliforms/ 100 ml. x 10^3	
	Free NH_3	Org. NH_3	Nitrite	Nitrate	Total	Soluble								Total	Faecal
Septic Tank	66.0	2.10	less than 0-001	less than 0-1	45	31	260	4.35	104	11	592	7.2	120	8,000+	8,000+
Bed 1	15.0	0.54	1.10	31.1	61	20	40	0.47	less than 1	less than 1	710	7.4	2.8	3,500	0.72
" 2	12.0	0.51	0.45	21.9	57	22	40	0.55	1.2	"	681	7.3	2.0	400	7.60
" 3	6.7	0.54	3.50	32.2	39	28	50	0.85	3.6	"	617	7.1	5.2	3,400	0.42
" 4	13.5	0.57	0.80	17.5	50	17	40	0.47	1.2	"	625	7.4	4.8	24	0.04
" 5	12.0	0.60	1.60	27.1	57	27	50	0.67	2.8	"	670	7.3	5.1	8,000	0.04
" 6	18.0	1.05	1.60	17.3	76	29	50	0.64	4.0	"	580	7.4	4.8	8,000	0.22

* Similar laboratory analyses are on file for remainder of period - September 1969 to June 1970.

TABLE 2

RAW SEWAGE

WHITBY PROJECT

Samples September 28 - 30, 1969

NITROGEN				PHOSPHATE MGS/LITRE			IRON MGS/LITRE		COD MGS/L	ABS MGS/L	TSS MGS/L	Volatile Solids MGS/L	Total Solids MGS/L	pH	BOD MGS/L	Coliforms/ 100 ml. x 10^3	
Free NH_3	Org.	Nitrate	Nitrite	Total	Ortho	Poly	Unfiltered	Filtered								Total	Faecal
41.610	8.700	less than 1	.115	53	42	11	5.40	.30	793.8	4.55	583	468	999	8.5		$+8 \times 10^6$	$+8 \times 10^5$
52.200	10.50	-	less than .001	77	69	8	-	-	3792	5.20	1860	1660	2064	8.4	735.0	-	-
53.250	12.350	-	"	115	95	20	-	-	3264	6.70	1720	1470	2972	7.9	740.0	-	-

TABLE 3

WATER USAGE

gallon/capita/day

House / Month	1	2	3	4	5	6	7	Community Average
<u>1969</u>								
October 69	39.0	22.2	26.3	33.0	26.0	25.2	32.2	29.1
Nov. 69	34.2	22.2	25.9	33.2	30.3	24.3	34.1	29.2
Dec. 69	39.4	18.0	28.3	31.5	28.3	25.8	30.2	28.6
<u>1970</u>								
Jan. 70	50.0	17.1	26.8	35.6	27.0	26.1	34.5	31.0
Feb. 70	41.8	14.9	34.3	34.6	27.5	26.9	33.3	30.4
March 70	46.7	19.1	37.5	32.9	28.9	26.6	35.3	31.0
April 70	39.4	21.1	34.1	33.5	24.0	29.9	34.7	30.9
May 70	37.7	19.2	32.8	30.2	27.9	21.3	34.4	29.1
June 70	42.0	23.1	44.4	32.4	34.5	49.3	61.1	40.9
July 70	49.6	21.2	25.6	27.4	30.0	1 –	48.0	33.6
Average	41.9	19.8	31.6	32.4	28.4	28.4	38.3	31.4
Number of Occupants A+C*	4	2 + 7	2 + 2	2 + 3	3	3	2 + 2	Total 32

* A – Adults
C – Children

TABLE 4

STATISTICAL ANALYSES

OF

SAMPLE RESULTS

BED 1

	% of time equal to or less than 15	50 Values	85
B.O.D.	3	4.6	7.0
C.O.D.	26	38	54
Suspended Solids	$\angle$1	1.8	5.0
Total Solids	620	700	800
Phosphates (Po4)			
Total	10	24	56
Ortho	6	14	31
Poly	1.9	6.2	21
Nitrogen (N)			
Free Ammonia	9.8	13	17
Organic	0.56	0.80	1.15
Nitrite	0.12	0.43	1.5
Nitrate	0.10	10	50
A.B.S.	0.45	0.94	2.0
Total Coliform/100 mil.	8,500	53,000	340,000
Fecal Coliform/100 mil.	170	5,000	140,000

* All values are in ppm except for Coliforms.

Computed values plotted on probability paper

TABLE 5

STATISTICAL ANALYSES OF SAMPLE RESULTS

BED 2

	% of time equal to or less than 15	50 Values	85
B.O.D.	1.2	2.9	7.0
C.O.D.	21	33	53
Suspended Solids	<1	<1	3.1
Total Solids	630	730	880
Phosphates (PO_4)			
Total	18	30	50
Ortho	12	16	22
Poly	5.0	7.4	11
Nitrogen (N)			
Free Ammonia	4.0	7.8	15
Organic	0.3	0.52	0.88
Nitrite	0.16	0.30	0.60
Nitrate	12	19	28
A. B. S.	0.20	0.54	1.5
Total Coliform/100 mil.	660	90,000	600,000
Fecal Coliform/ 100 mil.	60	10,000	160,000

* All values are in ppm excepting for Coliforms

T A B L E 6

STATISTICAL ANALYSES

of

SAMPLE RESULTS

BED 3

	% of time equal to or less than		
	15	50 Values	85
B.O.D.	1.2	3.2	8.6
C.O.D.	21	34	51
Suspended Solids	<1	<1	3.5
Total Solids	600	720	880
Phosphates (PO_4)			
Total	25	35	50
Ortho	13	21	35
Poly	7.4	11	15
Nitrogen (N)			
Free Ammonia	<0.1	3.1	8.0
Organic	0.17	0.35	0.76
Nitrite	0.19	0.60	1.9
Nitrate	19	27	40
A.B.S.	.27	.48	.86
Total Coliform/100 mil.	520	35,000	2,000,000
Fecal Coliform/100 mil.	180	4,400	100,000

* All values are in ppm excepting for Coliforms

T A B L E 7

STATISTICAL ANALYSES

OF

SAMPLE RESULTS

BED 4

	% of time equal to or less than 15	50 Values	85
B.O.D.	2.1	3.7	6.5
C.O.D	21	33	53
Suspended Solids	<1	1.3	3.0
Total Solids	580	720	910
Phosphates (PO_4)			
Total	18	32	58
Ortho	11	16	25
Poly	4.0	9.7	23
Nitrogen (N)			
Free Ammonia	2.5	15	21
Organic	0.29	0.60	0.94
Nitrite	0.12	0.42	1.5
Nitrate	12	19	29
A.B.S	0.29	0.48	0.78
Total Coliform/100 mil.	200	14,000	700,000
Fecal Coliform/100 mil.	7	1,500	350,000

* All values are in ppm excepting for Coliforms computed values plotted on probability paper (see graph No. 1)

T A B L E 8

STATISTICAL ANALYSES

OF

SAMPLE RESULTS

BED 5

	% of time equal to or less than 15	50 Values	85
B.O.D.	1.2	2.8	6.2
C.O.D.	22	33	48
Suspended Solids	< 1	1.6	4.2
Total Solids	620	715	880
Phosphates (PO_4)			
Total	20	30	47
Ortho	12	19	30
Poly	8.6	13	20
Nitrogen (N)			
Free Ammonia	0.30	4.0	13
Organic	0.17	0.42	1.05
Nitrite	0.10	0.40	1.6
Nitrate	16	25	37
A.B.S.	0.24	0.50	1.0
Total Coliform/100 mil.	340	40,000	4,300,000
Fecal Coliform/100 mil.	130	7,000	450,000

* All values are in ppm excepting for Coliforms

T A B L E 9

STATISTICAL ANALYSES

OF

SAMPLE RESULTS

BED 6

	% of time equal to or less than 15	50	85
	Values		
B.O.D.	2.7	5.2	10
C.O.D.	26	45	78
Suspendid Solids	1.8	4.3	10.5
Total Solids	540	660	800
Phosphates (PO_4)			
Total	23	33	48
Ortho	13	21	36
Poly	8	11	15
Nitrogen (N)			
Free Ammonia	2.9	8.8	27
Organic	0.31	0.76	1.9
Nitrite	0.26	0.64	1.6
Nitrate	11	16	24
A.B.S.	0.31	0.55	0.96
Total Coliform/100 mil.	10,000	540,000	8,000,000 +
Fecal Coliform/100 mil.	2,200	38,000	640,000

* All values are in ppm excepting for Coliforms

TABLE 10

STATISTICAL ANALYSES OF SAMPLE RESULTS FOR SEPTIC TANK EFFLUENT

	% of time equal to or less than		
	15	50 Values	85
B.O.D.	43	86	170
C.O.D.	82	180	400
Suspended Solids	45	72	180
Total Solids	550	660	790
Phosphates (PO_4)			
Total	20	37	68
Ortho	10	20	38
Poly	6	9.8	16
Nitrogen (N)			
Free Ammonia	17	26	40
Organic	1.3	1.8	2.5
Nitrite	.001	.001	.015
Nitrate	0.1	0.1	1.0
A.B.S.	2.2	3.3	5.0
Total Coliform/100 mil.	7,400,000	8,000,000 +	8,000,000 +
Fecal Coliform/100 mil.	250,000	800,000 +	800,000 +

* All values are in ppm excepting for Coliforms

TABLE 11

SUMMARY OF STATISTICAL ANALYSES*

B.O.D., C.O.D., A.B.S.,
ppm

Filter Bed	B.O.D.			C.O.D.			A.B.S.		
	% of time equal to or less than								
	15	50	85	15	50	85	15	50	85
	V A L U E S*								
Septic Tank Effluent	43	86	170	82	180	400	2.2	3.3	5.0
Filter Bed #1	3.0	4.6	7.0	26	38	54	.45	.94	2.0
Filter Bed #2	1.2	2.9	7.0	21	33	53	.20	.54	1.5
Filter Bed #3	1.2	3.2	8.6	21	34	51	.27	.48	.86
Filter Bed #4	2.1	3.7	6.5	21	33	53	.29	.48	.78
Filter Bed #5	1.2	2.8	6.2	22	33	48	.24	.50	1.0
Filter Bed #6	2.7	5.2	10.	26	45	78	.31	.55	.96

* Values taken From Tables 4 to 10

TABLE 12

SUMMARY OF STATISTICAL ANALYSES*

Total Coliforms - Faecal Coliforms
MPN per 100 ml.

Filter Bed	Total Coliforms 15	Total Coliforms 50	Total Coliforms 85	Faecal Coliforms 15	Faecal Coliforms 50	Faecal Coliforms 85
	% of time equal or less than					
	VALUES*					
Septic Tank Effluent	7,400,000	8,000,000+	8,000,000+	250,000	800,000+	800,000+
Filter Bed #1	8,500	53,000	340,000	170	5,000	140,000
Filter Bed #2	660	90,000	600,000	60	10,000	160,000
Filter Bed #3	520	35,000	2,000,000	180	4,400	100,000
Filter Bed #4	200	14,000	700,000	7	1,500	350,000
Filter Bed #5	340	40,000	4,300,000	130	7,000	450,000
Filter Bed #6	10,000	540,000	8,000,000+	2,200	38,000	640,000

* Values taken from Tables 4 to 10

TABLE 13

SUMMARY OF STATISTICAL ANALYSES*

Total Solids - T.S.S.

ppm

Filter Bed	Total Solids			T.S.S.*		
	% of time equal to or less than					
	15	50	85	15	50	85
	V A L U E S+					
Septic Tank Effluent	550	660	790	45	72	180
Filter Bed #1	620	700	800	<1	1.8	5.0
Filter Bed #2	630	730	880	<1	<1	3.1
Filter Bed #3	600	720	880	<1	<1	3.5
Filter Bed #4	580	720	910	<1	1.3	3.0
Filter Bed #5	620	715	880	<1	1.6	4.2
Filter Bed #6	540	660	800	1.8	4.3	10.5

* T.S.S. - Total Suspended Solids

\+ Values taken from Tables 4 to 10

TABLE 14

SUMMARY OF STATISTICAL ANALYSES*

Total Phosphates
Ortho Phosphates
Poly Phosphates

Filter Bed	Total Phosphates			Ortho Phosphates			Poly Phosphates		
	% of time equal to or less than								
	15	50	85	15	50	85	15	50	85
	V A L U E S*								
Septic Tank Effluent	20	37	68	10	20	38	6	9.8	16
Filter Bed #1	10	24	56	6.0	14	31	1.9	6.2	21
Filter Bed #2	18	30	50	12	16	22	5.0	7.4	11
Filter Bed #3	25	35	50	13	21	35	7.4	11	15
Filter Bed #4	18	32	58	11	16	25	4.0	9.7	23
Filter Bed #5	20	30	47	12	19	30	8.6	13	20
Filter Bed #6	23	33	48	13	21	36	8.0	11	15

* Values taken from Tables 4 to 10

TABLE 15

SUMMARY OF STATISTICAL ANALYSES

Free Ammonia (N) Organic Ammonia (N)
ppm

Filter Bed	Free Ammonia (N)			Organic Ammonia (N)		
	% of time equal to or less than					
	15	50	85	15	50	85
	VALUES +					
Septic Tank Effluent	17	26	40	1.3	1.8	2.5
Filter Bed #1	9.8	13	17	.56	.80	1.15
Filter Bed #2	4.0	7.8	15	.30	.52	.88
Filter Bed #3	< 0.1	3.1	8.0*	.17	.35	.76
Filter Bed #4	2.5	15	21	.29	.60	.94
Filter Bed #5	.30	4.0	13	.17	.42	1.05
Filter Bed #6	2.9	8.8	27	.31	.76	1.9

* Break in probability graph

\+ Values taken from Tables 4 to 10

TABLE 16

SUMMARY OF STATISTICAL ANALYSES

Nitrates
Nitrites
ppm

Filter Bed	Nitrates			Nitrites		
	% of time equal to or less than					
	15	50	85	15	50	85
	V A L U E S*					
Septic Tank Effluent	0.1	0.1	1.0	.001	.001	.015
Filter Bed #1	0.1	10	50	.12	.43	1.5
Filter Bed #2	12	19	28	.16	.30	.60
Filter Bed #3	19	27	40	.19	.60	1.9
Filter Bed #4	12	19	29	.12	.42	1.5
Filter Bed #5	16	25	37	.10	.40	1.6
Filter Bed #6	11	16	24	.26	.64	1.6

* Values taken from Tables 4 to 10

TABLE 17

TRACER DYE TESTS

Time in minutes for the Dye to be detected in Collector Buckets

Bed Dates	Sept. 12/69	Nov. 13/69	Dec. 30/69	April 6/70
Bed 1	14	140	341	overnight
Bed 2	15	160	217	176
Bed 3	3	62	27	95
Bed 4	16	340	overnight	overnight
Bed 5	2	27	37	56
Bed 6	2	9	17	10

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5. "Statistical Analysis of the Effluent Quality of Biological Sewage Treatment Processes", A. R. Townshend, O.W.R.C. Proceedings, The Third Canadian Symposium in Water Pollution, Vol. 3, Pg. 272 - 312, 1968

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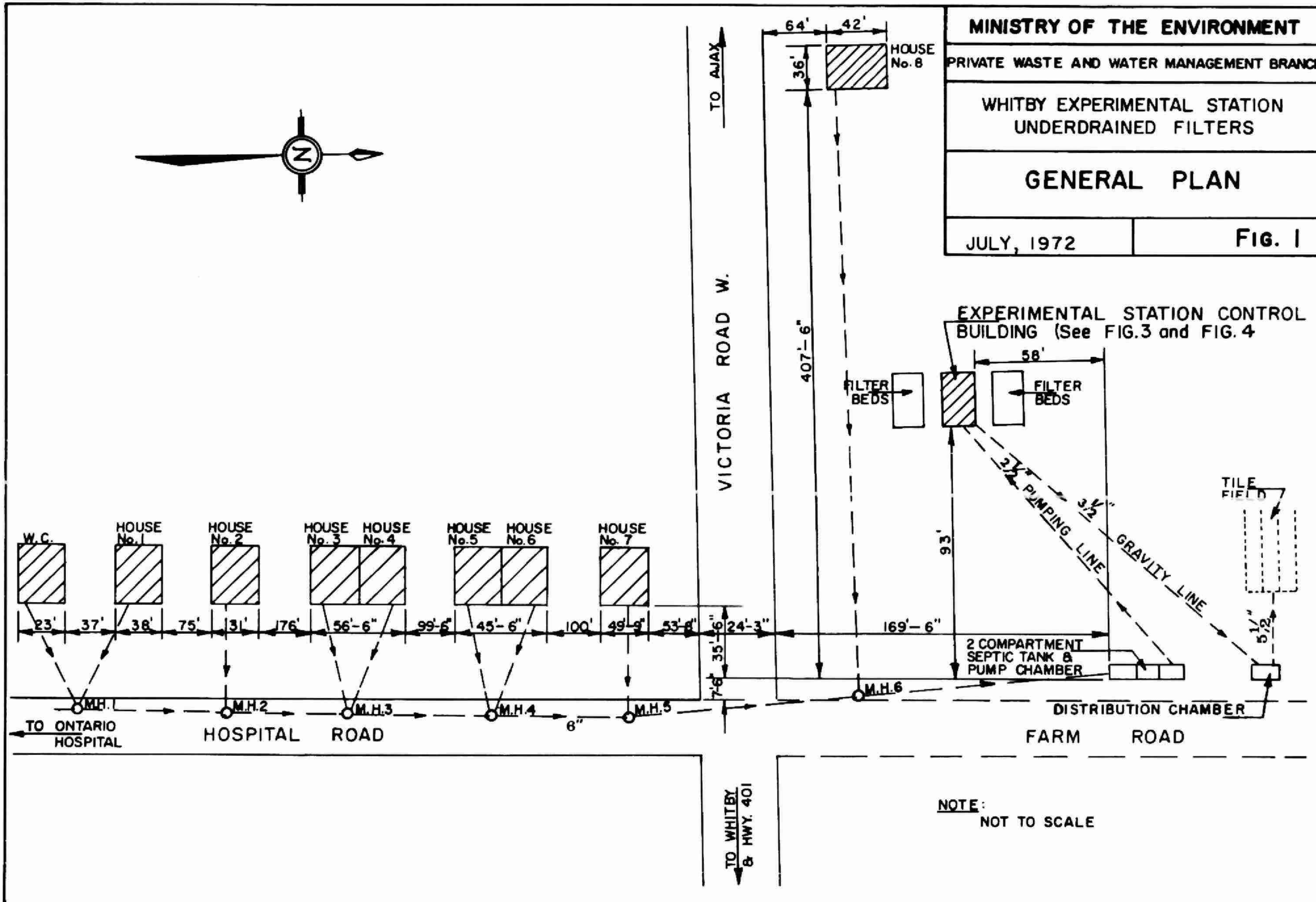
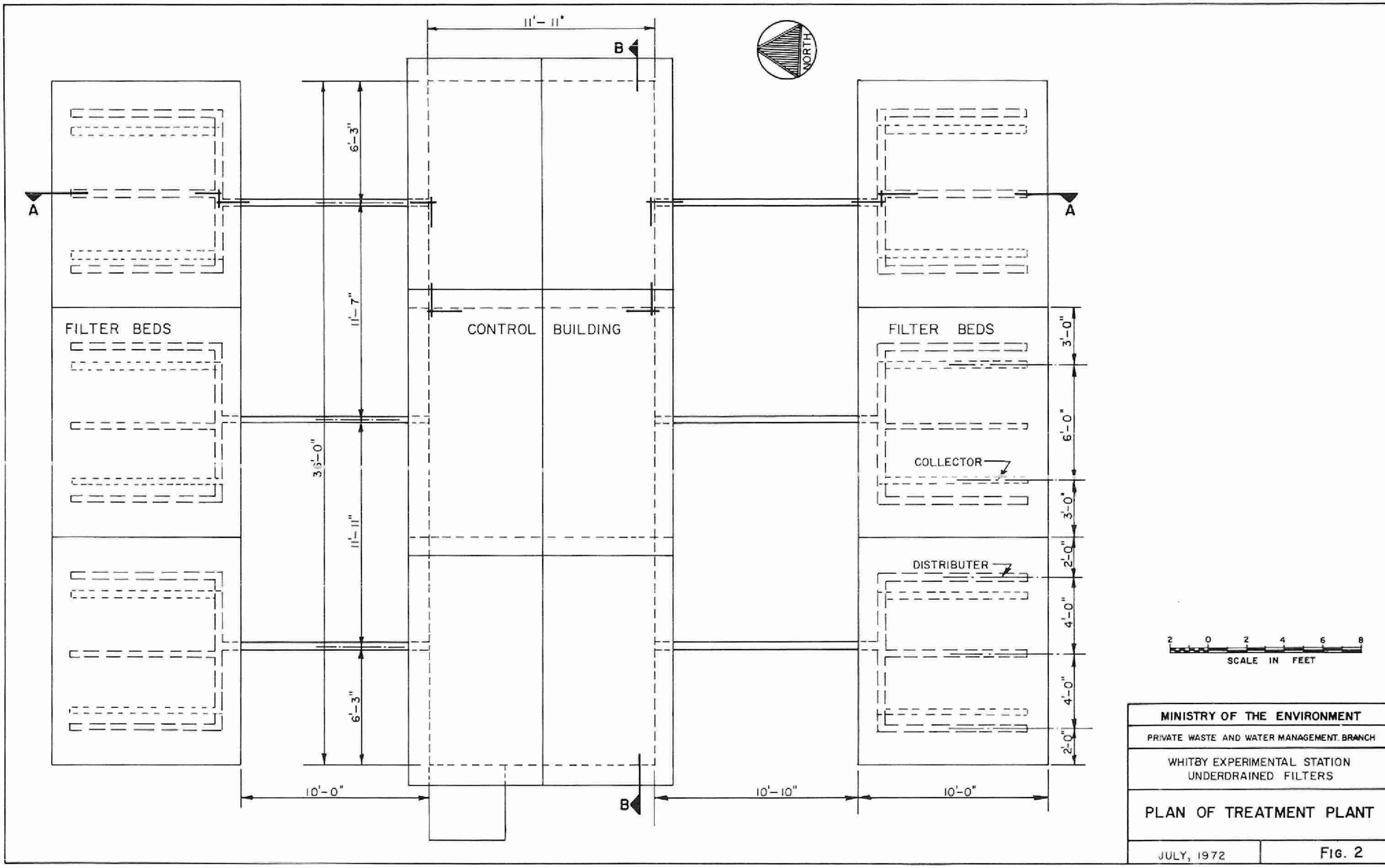

MINISTRY OF THE ENVIRONMENT
PRIVATE WASTE AND WATER MANAGEMENT BRANCH
WHITBY EXPERIMENTAL STATION
UNDERDRAINED FILTERS
GENERAL PLAN
JULY, 1972
FIG. 1
TO AJAX
64'
42'
HOUSE No. 8
36'
407'-6"
VICTORIA ROAD W.
EXPERIMENTAL STATION CONTROL BUILDING (See FIG. 3 and FIG. 4
58'
FILTER BEDS
FILTER BEDS
93'
2 1/2" PUMPING LINE
3 1/2" GRAVITY LINE
TILE FIELD
5 1/2"
W.C.
HOUSE No. 1
HOUSE No. 2
HOUSE No. 3
HOUSE No. 4
HOUSE No. 5
HOUSE No. 6
HOUSE No. 7
23'
37'
38'
75'
31'
176'
56'-6"
99'-6"
45'-6"
100'
49'-9"
53'-8"
6"
24'-3"
169'-6"
35'
7'-6"
2 COMPARTMENT SEPTIC TANK & PUMP CHAMBER
M.H. 1
M.H. 2
M.H. 3
M.H. 4
M.H. 5
M.H. 6
6"
DISTRIBUTION CHAMBER
TO ONTARIO HOSPITAL
HOSPITAL ROAD
FARM ROAD
TO WHITBY & HWY. 401
NOTE:
NOT TO SCALE



MINISTRY OF THE ENVIRONMENT

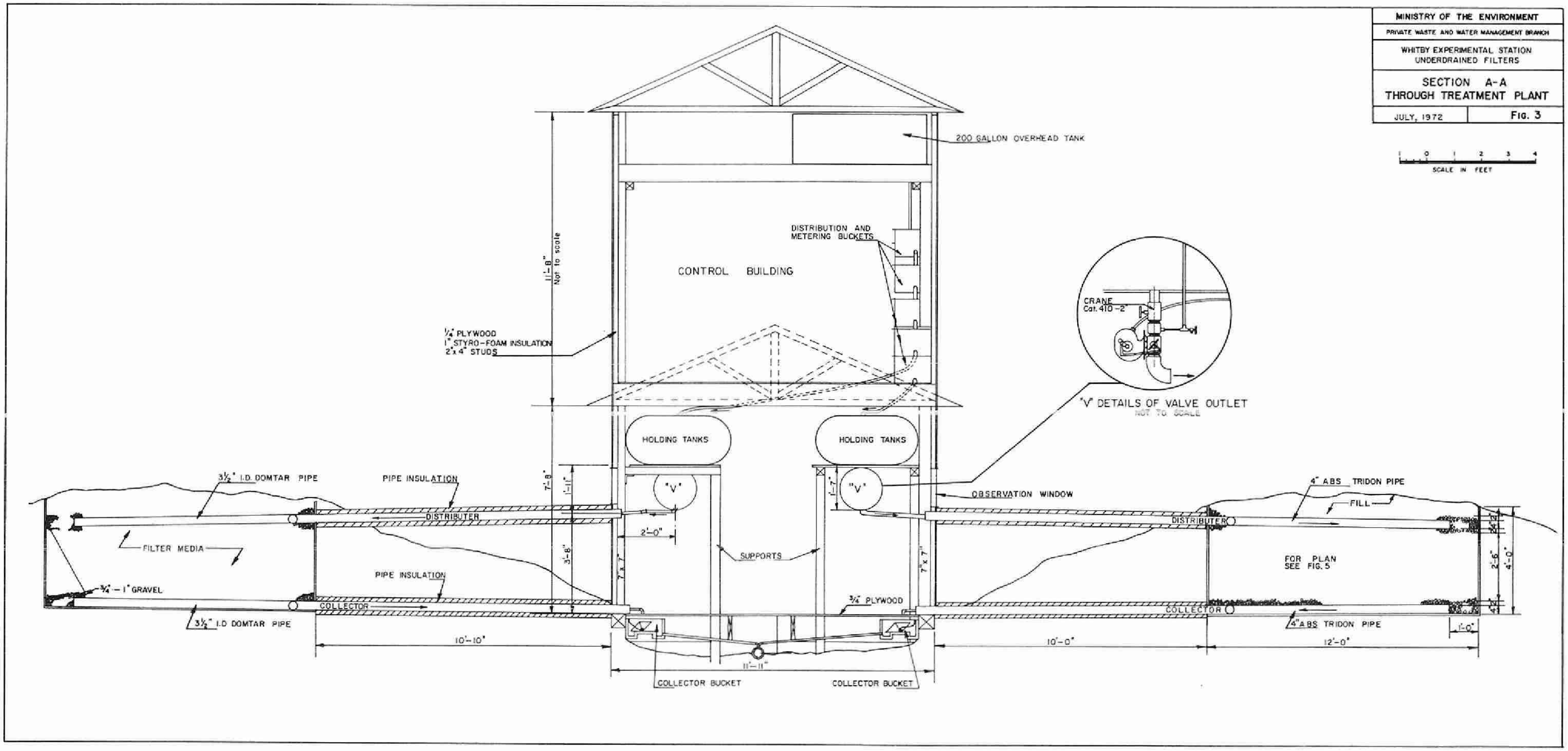
PRIVATE WASTE AND WATER MANAGEMENT BRANCH

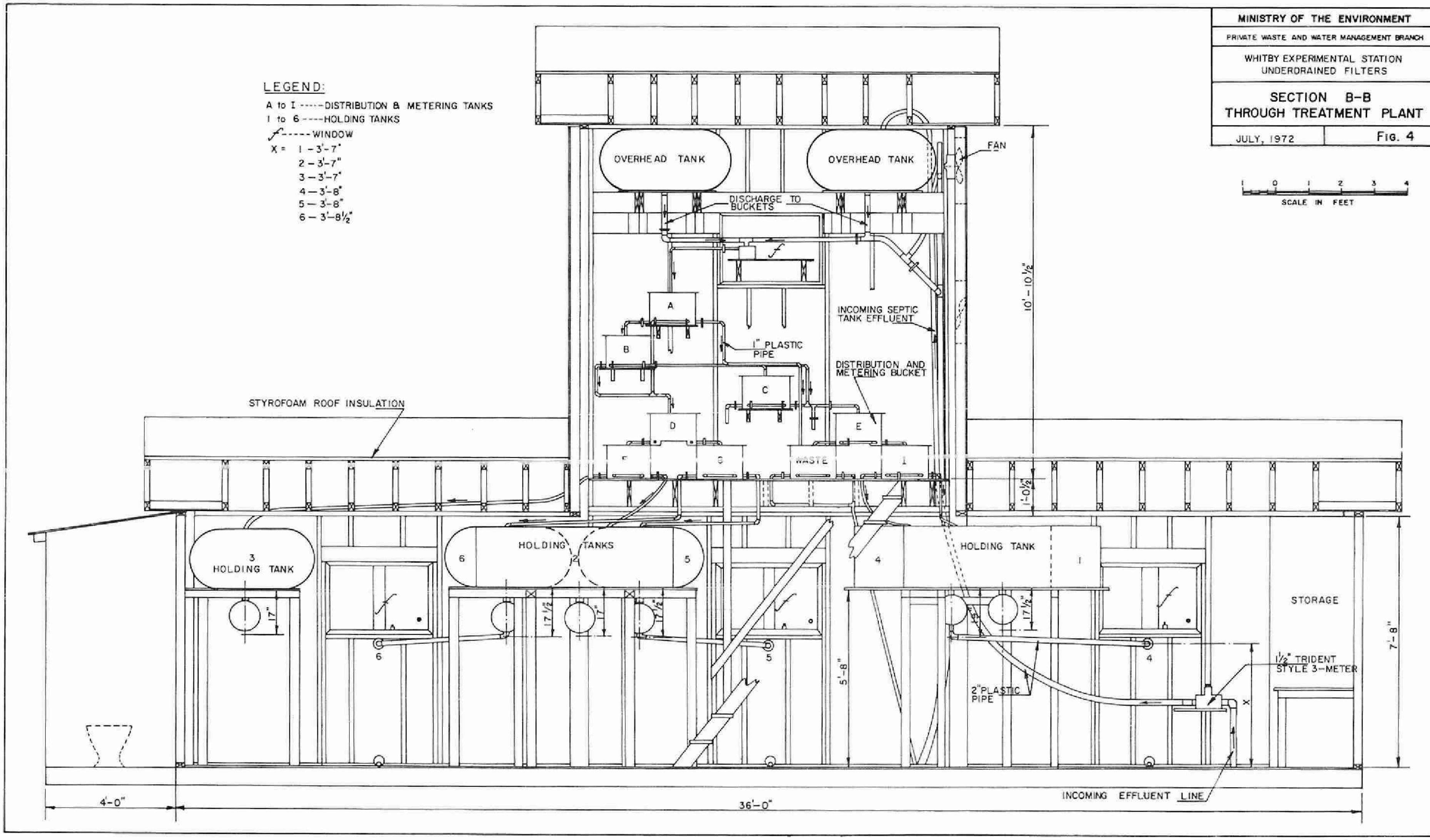
WHITBY EXPERIMENTAL STATION
UNDERDRAINED FILTERS

PLAN OF TREATMENT PLANT

JULY, 1972

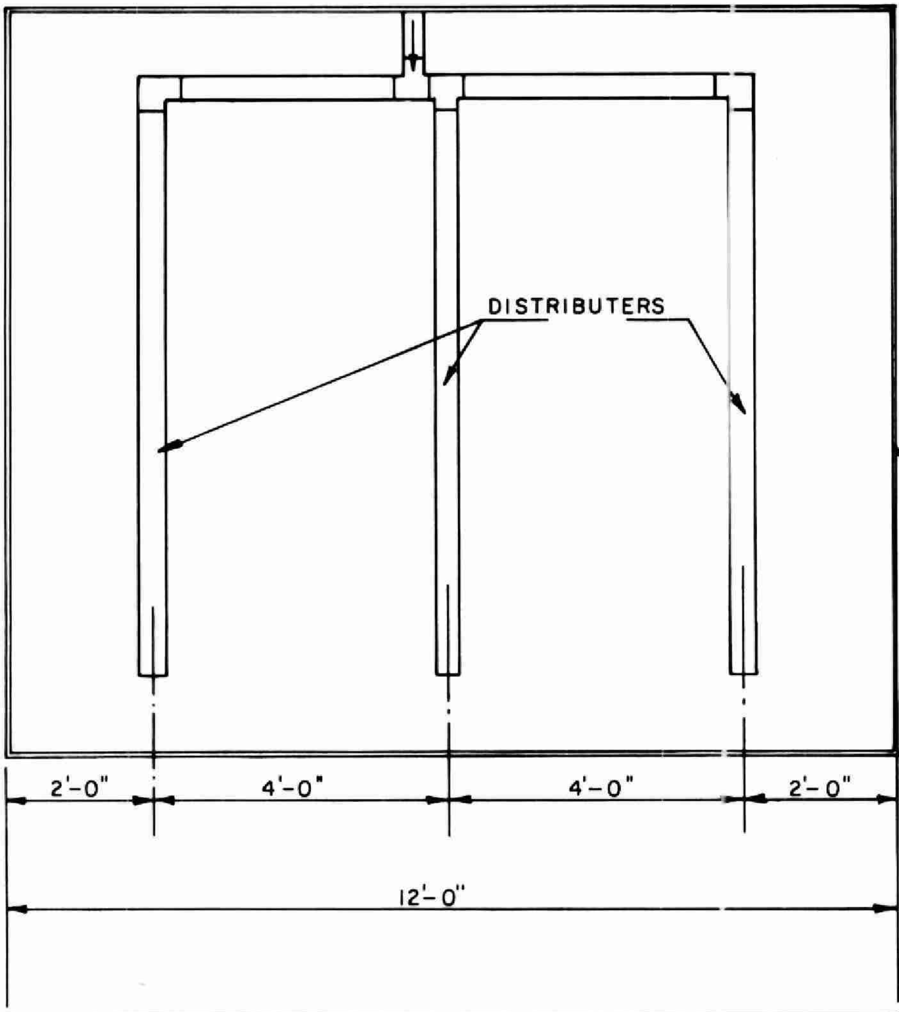
FIG. 2


MINISTRY OF THE ENVIRONMENT
PRIVATE WASTE AND WATER MANAGEMENT BRANCH
WHITBY EXPERIMENTAL STATION
UNDERDRAINED FILTERS
SECTION A-A
THROUGH TREATMENT PLANT
JULY, 1972
FIG. 3
SCALE IN FEET
200 GALLON OVERHEAD TANK
DISTRIBUTION AND METERING BUCKETS
CONTROL BUILDING
11'-8" Not to scale
1/4" PLYWOOD
1" STYRO-FOAM INSULATION
2"x 4" STUDS
CRANE
Cat. 410-2"
"V" DETAILS OF VALVE OUTLET
NOT TO SCALE
HOLDING TANKS
HOLDING TANKS
"V"
"V"
3½" I.D DOMTAR PIPE
PIPE INSULATION
OBSERVATION WINDOW
4" ABS TRIDON PIPE
FILL
DISTRIBUTER
DISTRIBUTER
FILTER MEDIA
SUPPORTS
FOR PLAN SEE FIG. 5
PIPE INSULATION
3/4"-1" GRAVEL
3/4" PLYWOOD
COLLECTOR
COLLECTOR
3½" I.D DOMTAR PIPE
4" ABS TRIDON PIPE
10'-10"
11'-11"
10'-0"
12'-0"
1'-0"
2'-0"
7'-8"
1'-11"
3'-8"
1'-7"
2'-6"
4'-0"
COLLECTOR BUCKET
COLLECTOR BUCKET



MINISTRY OF THE ENVIRONMENT
PRIVATE WASTE AND WATER MANAGEMENT BRANCH
WHITBY EXPERIMENTAL STATION
UNDERDRAINED FILTERS
SECTION B-B
THROUGH TREATMENT PLANT
JULY, 1972
FIG. 4

TYPICAL DISTRIBUTER LAYOUT

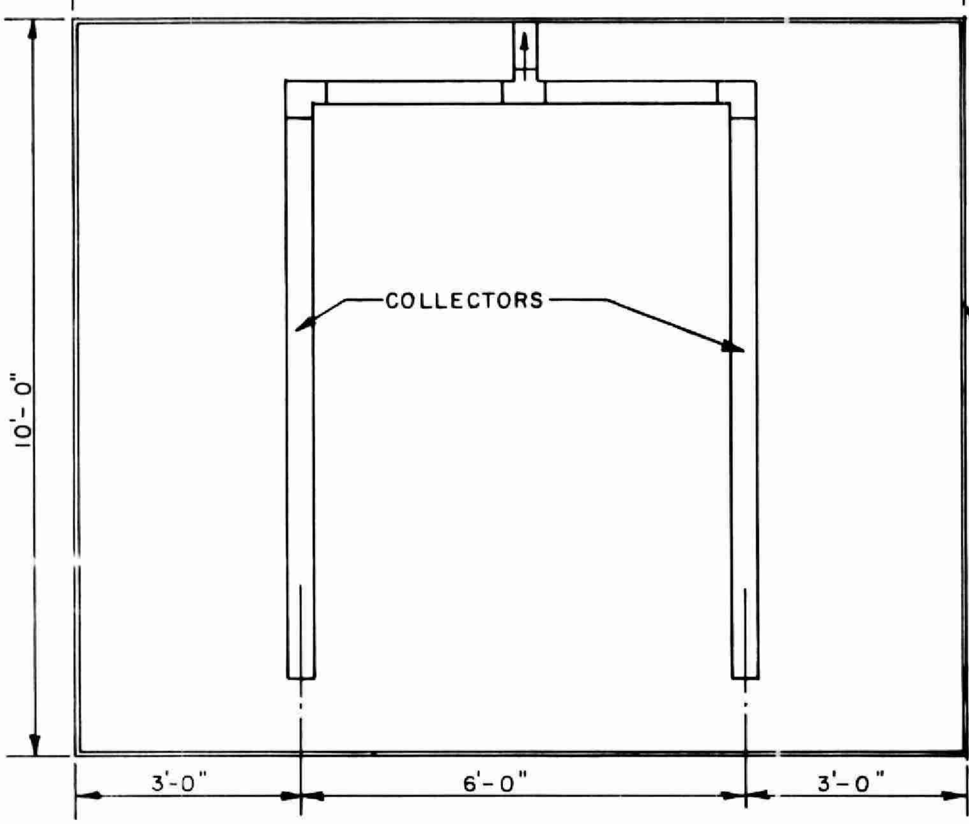


NOTE:

NORTH SIDE — All pipes 4" ABS Tridon, (perforated pipe inside the beds).

SOUTH SIDE — All pipes 3 1/2" Domtar, (perforated pipe inside the beds).

TYPICAL COLLECTOR LAYOUT



MINISTRY OF THE ENVIRONMENT	
PRIVATE WASTE AND WATER MANAGEMENT BRANCH	
WHITBY EXPERIMENTAL STATION UNDERDRAINED FILTERS	
DISTRIBUTER AND COLLECTOR LAYOUT PLAN	
JULY, 1972	FIG. 5